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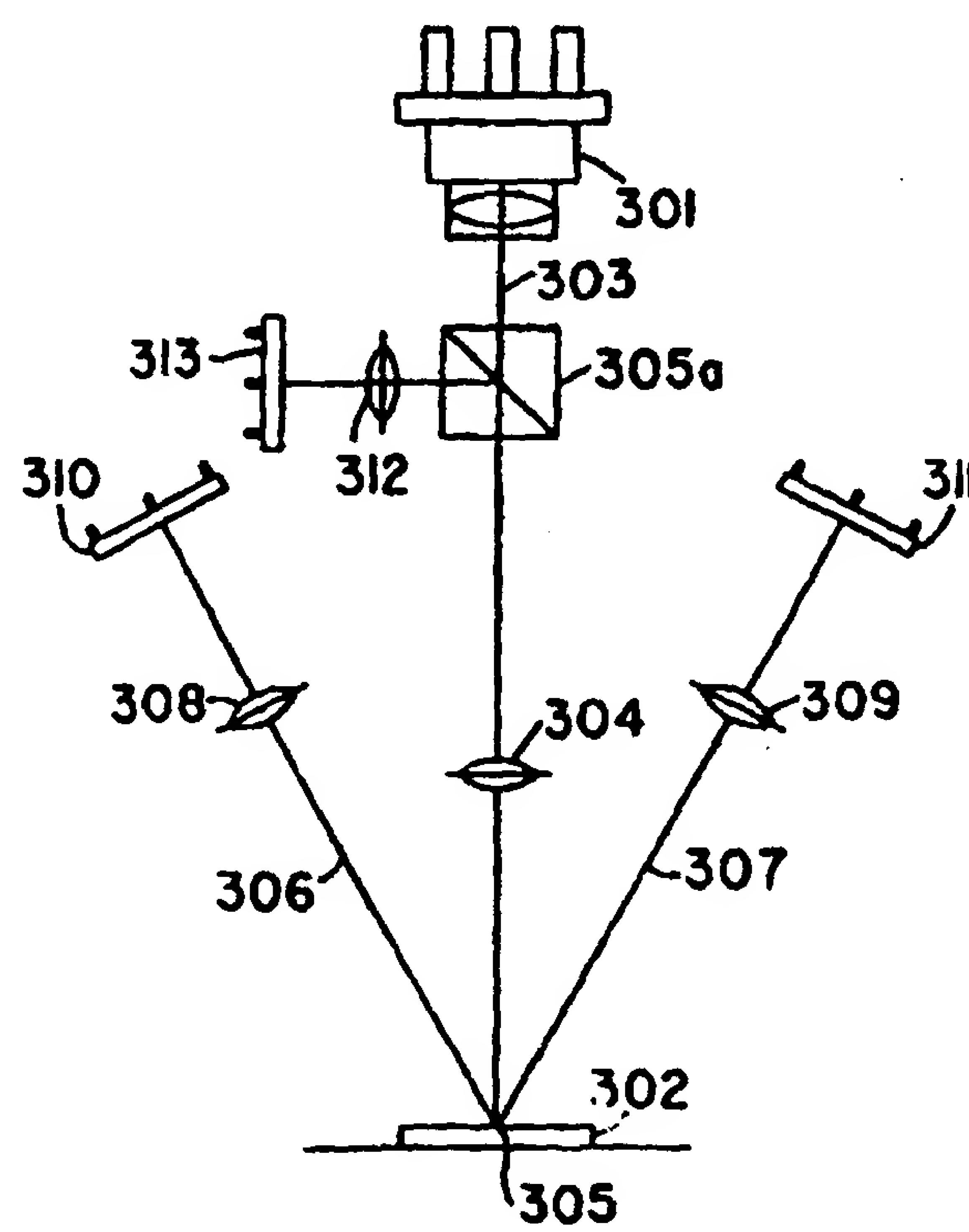
(54) Title: METHOD AND SYSTEM FOR MEASURING OBJECT FEATURES

(57) Abstract

A system is provided that simultaneously gathers three-dimensional and two-dimensional data for use in inspecting objects such as chip carriers for defects. Specifically, a source laser beam (303) is directed to an object and forms a spot (305) at the point of impingement at a known X-Y position on the object. The laser beam is reflected at the spot and light reflected off-axially (306, 307) with respect to the source laser beam (303) is detected by two position sensing detectors (PSDs) (310, 311). Simultaneous to detecting off-axially reflected light, retro-reflected light (i.e., the light reflected approximately co-axial with the source laser) is detected by a photo diode array (313). Three dimensional object information is determined from the position sensing detector (310, 311) signals and two-dimensional object information is determined from the photo diode array (313) signal.



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METHOD AND SYSTEM FOR MEASURING OBJECT FEATURES

Field of Invention

The present invention is directed to a method and system for measuring selected features of objects. In particular, the present invention is directed to simultaneously collecting three-dimensional and two-dimensional data concerning features of an object, and using such data to determine the dimensions and relative positions of the features.

Copyright Notice

Background of the Invention

The complexity of semiconductor chips has increased dramatically over the past several years. Such increased complexity has lead to an increase in the number of input and output leads or contacts required for each chip. Furthermore, the demand for a small "footprint," i.e., the amount of space required by a component on a printed circuit board, has lead to smaller and smaller package sizes.

In response to these demands, new semiconductor packages (also known as "chip carriers") have been developed that are small in size, yet have a large number of input and output leads or contacts. These packages include, for example, ball grid arrays (BGAs) which are slightly larger than the semiconductor die they package and having contacts (i.e., balls or bumps of solder) that are around 30 mils in diameter. Also, chip size packages (CSPs) which are about the size of the semiconductor die they package and having contacts that are around 10-15 mils in diameter. Additionally, "flip chips" have been developed wherein contacts are adhered directly to the semiconductor wafer, the contacts being approximately 5-10 mils in diameter.

The reduction in the diameter of contacts, and also the general shape of the new contacts, i.e., ball or bump, has made it increasingly difficult to accurately control the quality of the contacts on the semiconductor. In particular, there is a need to accurately measure the dimensions and location of the ball or bump contacts in order to compare the manufactured semiconductor chip (packaged or otherwise) to a manufacturer's specification.

One typical way of measuring the dimensions of contacts or leads on chip carriers is through the use of a three dimensional (3-D) vision system that employs optical triangulation techniques. U.S. Patent No. 5,465,252 issued to Bilodeau et al. (the "'152 patent"), expressly incorporated herein by reference, describes one such system. A light source such as a laser is positioned to illuminate an object (such as a packaged semiconductor chip) at a specific X-Y position. The source laser beam is directed through an optical system and forms a focused spot at the point of impingement on the object. The focused spot is reflected and light reflected off-axially with respect to the source laser beam is focussed on a light sensor. The image location (i.e., the point where the reflected spot impinges the light sensor) is related, using standard optics principals, to the location of the light spot on the object, which, in turn, can be used to determine image height (Z location). Calibrated processing electronics are used to calculate the height of the object and store the object height with its associated X-Y location. The light source is then positioned to different X-Y locations, and the process is repeated until 3-D data is gathered for the entire object (or a portion thereof). The stored data is then be compared to a manufacturer's specification for the object (or portion thereof) to determine whether the object is defective.

Known 3-D vision systems, such as the system described above, provide accurate results for measuring the dimensions of leads on chip carriers, and for coplanarity inspection of BGAs. However, there is difficulty in obtaining accurate dimensions (such as diameters) of ball, bump, and hemispherically shaped contacts, such as those found on certain chip carriers (e.g., BGAs). This difficulty is largely due to "shadow" effects. Known 3-D vision systems cannot accurately capture data concerning

all portions of each ball. These systems rely on complex curve-fitting algorithms to approximate the width of each ball. Accordingly, there is a need for a simplified process for accurately determine dimensional data regarding ball, bump, and hemispherically shaped contacts.

U.S. Patent No. 4,688,939 issued to Ray (the "'939 patent") describes a system for automatically inspecting bumps of solder on a major surface of a chip carrier. In accordance with the specification of the '939 patent, a chip carrier is placed on a platform beneath a ring light which is in registration with a television camera. Light from the ring light, which is directed at an angle towards all sides of the chip carrier, is only reflected upwardly into the television camera by solder bumps. The output signal of the television camera, which varies with the intensity of the light reflected from the solder bumps, is processed by a vision system to obtain a one-dimensional plot of the light intensity. The intensity plot is then analyzed for missing, bridged, or excessive solder bumps. This system, however, collects only one-dimensional data concerning the chip carrier. If 2- or 3-D data is desired, a separate vision system must be used.

Furthermore, the system described in the '939 patent requires that the area surrounding the solder bumps be very diffuse, serving to scatter rather then reflect light. Accordingly, measurements of solder bumps on chip carriers made of more reflective material will likely prove inaccurate.

Summary of the Invention

The present invention is directed to a system for quickly and accurately measuring features of objects. In an

exemplary embodiment, a system is provided that simultaneously collects three-dimensional and two-dimensional data for use in inspecting objects such as chip carriers for defects. Specifically, a source laser beam is directed to an object and forms a spot at the point of impingement at a known X-Y position on the object. The laser beam is reflected at the spot and the light reflected off-axially with respect to the source laser beam is detected by two position sensing detectors (PSDs).

Simultaneous to detecting off-axially reflected light, retro-reflected light (i.e., the light reflected approximately co-axial with the source laser) is detected by a photo diode array. In this manner, visibility is obtained to the entire upper hemisphere of features such solder balls and bumps.

Analog signals generated by the PSDs related to the position(s) where the reflected light impinged the PSDs, are used to calculate the Z coordinate of the object (i.e., the height) at the point of impingement of the source laser beam on the object. This value is calculated using standard optical triangulation principals. The three-dimensional (3-D) information can then be compared to manufacturer's specifications for the chip carrier to determine if, for example, each solder ball or bump on a chip carrier such as a ball grid array, is the correct height. Additionally, the information can be used for determining coplanarity.

The amplitude of the reflected light that is received by each PSD at the known X-Y positions may be used to form an image of the reflected energy on a point by point basis. However, the resulting images (one per PSD) will suffer from the same shadowing effects as the three dimensional data that is simultaneously gathered.

Analog signals generated by the photo diode array related to the intensity of the detected retro-reflected light are used to accurately determine the X and Y diameters of each ball/bump on the chip carrier and also determine the X-Y coordinates of the center of each ball/bump. The present invention recognizes that laser beams grazing the edge of a feature such as a ball or bump have lower intensity reflections that the beams striking the center of each ball/bump, or the area surrounding each ball/bump. Accordingly, the intensity value for each X-Y position is compared to a threshold value. If the intensity value is less than the threshold value, the X-Y position is identified as an edge point of a ball/bump.

The two-dimensional image formed by the identified edge points is projected onto the X-axis and also onto the Y-axis. The projected images are then used to determine the relative position of each ball, the diameter of each ball (in both the X and Y directions), and also the center of each ball.

Additionally, the analog signals generated by the 2-D photo diode array (for example, a two axial position sensitive device) also provide information related to the position where the reflected light impinged the array. Since the 2-D diode array is located on the imaging plane of the chip carrier under measurement, the positional information can be used to determine the exact X-Y position of the laser during scanning.

Brief Description of the Drawings

The foregoing and other features of the present invention will be more readily apparent from the following detailed

description of exemplary embodiments taken in conjunction with the attached drawings wherein:

Fig. 1 is a diagram of a prior art vision system;
Fig. 2 is an illustration of "shadow" effects;
Fig. 3 is a diagram of a first exemplary embodiment of the present invention;
Fig. 4 is a flowchart illustrating the categorization of each collected intensity value in the 2-D array;
Fig. 5 is the 2-D image of a solder ball as categorized by the process of Fig. 4;
Fig. 6 is a flowchart of the determination of a threshold intensity value;
Fig. 7 is a histogram of a 2-D image of a exemplary solder ball on a BGA;
Fig. 8 is a flowchart of the analysis of the 2-D categorized data;
Fig. 9 illustrates the projection of a 2-D image onto the X and Y axes;
Fig. 10 is a flowchart of the analysis of the 3-D data;
Fig. 11 is a block diagram of a second representative embodiment of the present invention; and
Fig. 12 is a block diagram showing further details of the optical system of Fig. 11.

Detailed Description

Prior Art Vision System: Referring now to the drawings, and initially Fig. 1, there is illustrated a typical prior art vision system. A source of light, i.e., laser 101, is positioned to illuminate an object such as a chip carrier 102. A laser beam 103 from laser 101 is directed through an optical system 104 and forms a focused spot 105 at the point of impingement on the chip carrier 102 at a known X-Y position. The laser beam 103 focussed at spot 105 is reflected. The light reflected off-axially

with respect to the source laser beam (106, 107) is focussed through two optical systems 108 and 109 on to two PSDs 110 and 111. The image height (Z-location) is then calculated based on where the reflected spot impinges the light sensor using standard optical triangulation principals. The laser beam is then directed to different X-Y positions on the chip carrier 102 and the procedure is repeated until 3-D data is gathered for the entire region of interest on the chip carrier 102. A system configured in a manner similar to the system just described has also been used to collect 2-D information. A system of this type, however, cannot directly measure certain features on a chip carrier due to "shadow effects."

Shadow Effects: Fig. 2 illustrates two shadow effects. First, the figure illustrates a shadow area blocked from being illuminated by a beam. As shown, laser beams 201-203 can only scan the upper half of solder ball 204, i.e., the area above line AB. The laser beams 201-203 cannot illuminate the remaining portion of the ball 204 since it is blocked by the top half of the solder ball 204.

A second shadow effect is caused by the limited visibility of the receiver system (i.e., optical system 108 and PSD 110). As illustrated, the area visible to the receiver system, i.e., the area above line CD, is even smaller than a hemisphere. This is due to the finite distance between the receiver optics and the solder ball 204, as well as the finite size of the receiver optics.

As a result of the two above described shadow effects, the measurable area of solder ball 204 is the overlap area of AC and CD, i.e., the area above CB. Accordingly, the diameter of the solder call cannot be directly

measured, but it can be determined using complex fitting techniques. However, the accuracy of the results obtained may be less than the required accuracy.

Exemplary Embodiment: Fig. 3 is a diagram of an exemplary embodiment of the present invention which overcomes many of the problems found in the prior art. A source of light, laser 301 (e.g., a gas laser, or a laser diode and collimator), is positioned to illuminate an object such as a chip carrier 302. A laser beam 303 from laser 301 is directed through a beam splitter 305a and is focussed through an optical system 304 to form a focused spot 305 at the point of impingement on the chip carrier 302 at a known X-Y position. (It will be understood by those of ordinary skill that the light may, instead, be focussed or deflected as a slit, plane of light, or other shape.) The laser beam 303 is reflected by the chip carrier 302 at spot 305. The light reflected off-axially with respect to source laser beam 303 (306, 307) is focussed through two optical systems 308 and 309 on two photo sensitive devices such as, for example, PSDs 310 and 311. (It should be noted that other photo sensitive devices can also be used such as, for example, charge coupled devices (CCDs), or photo diode arrays.) The height (Z-location) at the X-Y position of the object (at the point of impingement of the source laser beam) is then calculated as was described in connection with Fig. 1. Accordingly, 3-D data (i.e., X, Y, and Z coordinates) is obtained, providing a 3-D image of the object at that X-Y location of the object. It will be understood by those of ordinary skill that the 3-D data can be obtained by detecting light reflected (off-axially with respect to the source laser beam) along a single path (and, accordingly, using a single photo sensitive device) rather than along two paths as described above.

2-D Data Capture: In the exemplary embodiment of the present invention, retro-reflected light is also detected and measured (simultaneously to detecting the off-axially reflected light) in order to, for example, provide visibility to the entire upper hemisphere of a feature such as a solder ball or bump (at least a portion of which is not visible to the PSDs 310 and 311). In particular, light reflected at focused spot 305 on the chip carrier 303 back toward the laser 301, i.e., retro-reflected light (light reflected approximately co-axial with the source laser beam 303), is focussed and directed through the optical system 304 to the beam splitter 305. The beam splitter 305 reflects the retro-reflected light through an optical system 312 onto a photo sensitive device, such as, for example photo diode array 313 (other photo sensitive devices, such as a single photo diode can also be used). The value of the light intensity for each X-Y position is stored in a 2-D array (such as Y(i,j)). Accordingly, a 2-D image of the object at the X-Y position is obtained.

The above described procedure (the 3-D and 2-D data collection) is repeated until the entire object (or a relevant portion thereof) is scanned (i.e., many X-Y positions on the object are imaged).

Categorization Of Intensity Values In 2-D Array: Once the 2-D data is obtained, the information is analyzed. In the representative embodiment of the present invention, it is recognized that laser beams grazing the edge of solder balls or bumps have lower intensity retro-reflections than those striking the center of the solder balls or bumps, and also lower intensity retro-reflections than those beams striking the area surrounding the balls or bumps. Accordingly, X-Y intensity values in the 2-D array are categorized as illustrated in the flowchart of Fig. 4. Indexes i and j

are first initialized to refer to the first X-Y intensity value (step 401). Intensity value Y(i,j) is compared to a threshold intensity value T (step 402) (the determination of the threshold value is described below in connection with Fig. 6). If Y(i,j) has an intensity value that is greater than the threshold value T, then Y(i,j) is designated "background" (i.e., it is either the center of the ball/bump or the area surrounding the ball/bump), thus l(i,j) (wherein l(i,j) denotes the label of Y(i,j)) is set to 0 (step 403). If, however, Y(i,j) has an intensity value that is less threshold value T, then Y(i,j) is an edge point of the ball/bump and l(i,j) is set to 1 (step 404). This process is repeated until all of the intensity values in the 2-D array have been compared to the threshold value T (see steps 405, 406). For solder balls and bumps, a typical result is a ring shaped image as shown in Fig. 5.

Determination of a Threshold Intensity Value: In the representative embodiment of the present invention, the threshold value is determined using a fast, iterative procedure as shown in the flowchart of Fig. 6. First, a portion of a sample chip carrier, for example, a portion including a solder ball, is imaged using the system described in connection with Fig. 3 (step 601). In the representative embodiment, only the 2-D data collected from the photo diode array 313 is utilized in the threshold value determination. Thus the 3-D data collected from PSDs 310 and 311 need not be stored.

Next, the cluster center M (i.e., the mass center) of the data is determined (step 602). In particular:

$$M = 1/N * \sum_{i,j} Y(i,j),$$

where N is the total number of data samples (i.e., an averaging function). M is then split into two new cluster centers, i.e., M0 = M + p and M1 = M - p

where p is a small predetermined perturbation value (step 603). Typically, p is chosen as p = 0.001*M.

Each X-Y intensity value is then classified into one of two classes using the nearest distance rule (step 604). That is:

l(i,j) = 0 if D(Y(i,j), M0) < D(Y(i,j), M1);

l(i,j) = 1 if D(Y(i,j), M0) > D(Y(i,j), M1);

where D is a distance function (e.g., D(a,b) may be defined as the absolute value of a-b) and l(i,j) denotes the label of the data Y(i,j).

The cluster centers are then updated (step 604) as follows:

$$M0 = 1/N0 * \sum_{i,j} Y(i,j) \text{ for } l(i,j) = 0,$$

where N0 is the total number of data points where l(i,j) = 0;

$$M1 = 1/N1 * \sum_{i,j} Y(i,j) \text{ for } l(i,j) = 1$$

where N1 is the total number of data points where l(i,j) = 1.

Then, the threshold value is updated (step 605):

T=0.5 * (M0 + M1).

This process continues until convergence is reached. Fig. 7 shows a histogram of a 2-D image of a exemplary solder ball on a BGA.

Analysis of 2-D Data: Once each of the X-Y intensity values are categorized as described in connection with Fig. 4, the 2-D image (i.e., the image formed by the edge points) is analyzed in accordance with the flowchart of Fig. 8. The image is first projected onto the X-axis (step 801). X positional information and the X diameter of each ball is then determined based on the projection, i.e., X diameter = X2 - X1 (where X1 and X2 are the minimum and maximum X coordinates of the projected image)

(step 802). Additionally, the X center position is calculated (step 803), i.e., X center = X1 + (X2 - X1)/2.

Next, the 2-D image is projected onto the Y-axis (step 804). Y positional information and the Y diameter of each ball is determined based on this projection, i.e., Y diameter = Y2 - Y1 (where Y1 and Y2 are the minimum and maximum Y coordinates of the projected image)(step 805). The Y center position is then calculated (step 806), i.e., Y center = Y1 + (Y2 -Y1)/2.

The combination of the two center coordinates, i.e., X center and Y center, defines the ball center coordinates (step 807), i.e., ball center = (X center, Y center).

It will be understood by those of ordinary skill that the order of the steps illustrated in the flowchart of Fig. 8 is merely exemplary. Many of the steps could be done in a different order.

Fig. 9 illustrates the projection of the 2-D image onto the X and Y axes. Specifically, image 901 is shown projected onto the X axis 902, and the Y axis 903.

Analysis of the 3-D Data: In the representative embodiment of the present invention, the 3-D data is analyzed to determine i) the height of each solder ball; and ii) chip carrier coplanarity. In accordance with the flowchart of Fig. 10, the data collected from PSDs 310 and 311 is used to determine the height of each solder ball in accordance with well-known optical triangulation techniques (step 1001). As is understood by those of ordinary skill, the point where a reflected spot impinges the PSDs 310 and 311 is related to the location of the light spot on the object, which, in turn, can be used to determine image height (Z location). The respective image heights can then be compared to each other in order

to determine chip carrier coplanarity (step 1002). In particular, each solder ball/bump should appear to be approximately the same height if the chip carrier is flat.

Wide Light Beam: When the light source 301 (of Fig. 3) transmits a wide beam of light, 2-D and 3-D images of a large area of the object 302 can be obtained. For example, assuming photo sensitive device 313 is a photo diode array, light retro-reflected from the object will be detected by several diodes in the array. Accordingly, information (e.g., intensity values) concerning several X-Y coordinates of the object, will be simultaneously collected by the diodes. If a feature is narrower than the laser beam, a dimension (such as, for example, a diameter) can be determined after a single pulse of the laser beam. The two PSDs 310 and 311 will then generate signals related to an average Z value of the area.

Second Exemplary Embodiment: Fig. 11 is a block diagram of a second exemplary embodiment of the present invention. As illustrated, an optical system 1101 is mounted on a gantry 1102, and positioned above an object to be measured such as a chip carrier 1103. The gantry 1102 may include, for example, a motion mechanism (not shown) such as that described in U.S. Patent No. 5,463,227 issued to Stern et al., expressly incorporated herein by reference, for positioning the optical system 1101 to different X-Y positions above the chip carrier 1103. The motion mechanism may be controlled by a computer 1104 (which includes, for example, a microprocessor 1104a, a memory device 1104b and a program storage device 1104c) to maintain a constant speed during scanning. The position of the scanning axis is transmitted by the computer 1104 to the process electronics 1105.

1205 reflects light that is polarized in a direction perpendicular to the surface of the page. Since the laser beam 1203 has a polarization that is primarily in the horizontal direction (in the plane of the page), most of the laser beam 1203 will pass through the beam splitter 1205. (However, a small portion of the laser beam 1203 is reflected and optionally detected for normalizing purposes by photo diode array 1219 through optical system 1218 (comprised of, for example, an achromatic lens, f=50mm). From the beam splitter 1205, the laser beam 1203 passes through a quarter wave plate 1207 (which changes the linear polarized light to a circular polarization), and is focussed and directed through an optical system 1208 (e.g., a lens, f=25mm) to form a focused spot 1209 at the point of impingement on the chip carrier 1202 at a known X-Y position. The laser beam 1203 impinging the object 1202 at focused spot 1209 is reflected. The light reflected off-axially with respect to the laser beam 1203 (1210, 1211) is focussed through two optical systems 1212 and 1213 (each comprised of, for example, two lenses: f=38.1mm and 88.9mm, and a gold mirror) on to two photo sensitive devices, such as PSDs 1214 and 1215. Analog signals generated by the PSDs 1214 and 1215 related to the detected position where the reflected light impinged the PSDs 1214 and 1215 are transmitted to the process electronics 1105.

In the second exemplary embodiment of the present invention, retro-reflected light is also detected and measured (simultaneously to collecting the 3-D data). In particular, light reflected from the focused spot 1209 back toward the light source 1201, i.e., retro-reflected light, is focussed and directed through optical system 1208 and quarter wave plate 1207 to beam splitter 1205. The quarter wave plate 1207 changes the polarization of the retro-ref .cted light to a linear polarization and the polarization is in a direction that is perpendicular

While the present invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A method for determining at least two dimensions of an object comprising the steps of:

a) illuminating at least a portion of the object with light transmitted by a light source along a first path;

b) detecting light reflected along a second path spaced from the first path from the object at a first preselected position;

c) forming a first image of the illuminated portion of the object as a function of the light detected in step b);

d) simultaneously with step b), detecting light retro-reflected within the first path from the object at a second preselected position;

e) forming a second image of the illuminated portion of the object as a function of the light detected in step d;

f) determining at least one first dimension of the object as a function of the first image; and

g) determining at least one second dimension of the object as a function of the second image.

2. The method of claim 1 wherein step a) further comprises:

illuminating the at least a portion of the object at a predetermined X-Y coordinate.

3. The method of claim 2 wherein the at least one first dimension is a Z coordinate of the object.

4. The method of claim 2 wherein the at least one first dimension is a plurality of Z coordinates of the object.

5. The method of claim 1 wherein step g) further comprises the steps of:

h) comparing the intensity of the second image to a threshold value;

i) forming a two dimensional image of the at least a portion of the object as a function of results of step h);

j) projecting the two dimensional image onto an axis; and

k) determining the at least one second dimension as a function of the projected image of step j).

6. The method of claim 5 further comprising the steps of:

l) obtaining a plurality of intensity values, the plurality of intensity values related to a sample object;

m) determining a first cluster center as a function of the plurality of intensity values;

n) determining first and second associated cluster centers, each a function of the first cluster center;

o) associating a first subset of the plurality of intensity values with the first associated cluster center;

p) associating a second subset of the plurality of intensity values with the second associated cluster center, wherein the second subset is different than the first subset;

q) updating the first associated cluster center as a function of the first subset;

r) updating the second associated cluster center as a function of the second subset;

s) repeating steps p-r until the first associated cluster center and the second associated cluster center converge; and

t) determining the threshold value as a function of converged first associated cluster center and second associated cluster center.

7. The method of claim 6 wherein the function of step q is an averaging function.

8. The method of claim 1 wherein the at least one second dimension is an edge coordinate of a feature on the object.

9. The method of claim 1 wherein the at least one second dimension is a diameter of a feature on the object.

10. A method for determining at least two dimensions of an object comprising the steps of:

a) illuminating at least a portion of the object at a predetermined X-Y coordinate with light transmitted by a light source along a first path;

b) detecting light reflected along a second path spaced from the first path from the object at a first preselected position;

c) forming a first image of the illuminated potion of the object as a function of the light detected in step b);

d) simultaneously with step b), detecting light retro-reflected within the first path from the object at a second preselected position;

e) forming a second image of the illuminated portion of the object as a function of the light detected in step d;

f) repeating steps a) - e) for a plurality different portions of the object at respective X-Y coordinates thereby forming a plurality of first respective images and a plurality of second respective images;

g) determining at least one first dimension of the object as a function of each of the plurality of first respective images; and

h) determining at least one second dimension of the object as a function of each of the plurality of second respective images.

11. The method of claim 10 wherein step h) further comprises the steps of:

i) comparing the intensity of each of the plurality of respective second image to a threshold value;

j) forming a two dimensional image of the at least a portion of the object as a function of results of step h);

k) projecting the two dimensional image onto an axis; and

l) determining the at least one second dimension as a function of the projected image of step j).

12. The method of claim 10 wherein the at least one second dimension is a diameter.

13. A method of imaging an object comprising the steps of:

a) illuminating at least a portion of the object at a predetermined X-Y coordinate with light transmitted by a light source along a first path;

b) detecting light reflected along a second path spaced from the first path from the object at a first preselected position;

c) forming a first image of the illuminated portion of the object as a function of the light detected in step b);

d) simultaneously with step b), detecting light retro-reflected within the first path from the object at a second preselected position; and

e) forming a second image of the illuminated portion of the object as a function of the light detected in step d).

14. A method for determining at least one dimension of an object comprising the steps of:

a) obtaining a plurality of intensity values, the plurality of intensity values related to a sample object;

b) determining a first cluster center as a function of the plurality of intensity values;

c) determining first and second associated cluster centers, each a function of the first cluster center;

d) associating a first subset of the plurality of intensity values with the first associated cluster center;

e) associating a second subset of the plurality of intensity values with the second associated cluster center, wherein the second subset is different than the first subset;

f) updating the first associated cluster center as a function of the first subset;

g) updating the second associated cluster center as a function of the second subset;

h) repeating steps e-g until the first associated cluster center and the second associated cluster center converge; and

i) determining a threshold value as a function of converged first associated cluster center and second associated cluster center;

j) illuminating at least a portion of the object with light transmitted by a light source along a first path;

k) detecting light retro-reflected within the first path from the object at a preselected position;

l) forming a second image of the illuminated portion of the object as a function of the light detected in step d; and

m) determining at least one dimension of the object as a function of the first image and the threshold value.

15. A system for imaging an object comprising:
a light source positioned to transmit light along a first path for illuminating at least a portion of the object;
a first photo sensitive device at a first preselected position for detecting light reflected along a second path spaced from the first path from the object and for generating a first signal representing information concerning the light detected along the second path;
a second photo sensitive device at a second preselected position for detecting light retro-reflected along the first path from the illuminated portion of the object and for generating a second signal representing information concerning the light detected along the first path; and
processing means, in communication with the first and second photo sensitive devices, for receiving the first signal and for generating a first image of the at least a portion of the object as a function of the received first signal, and for receiving the second signal and for generating a second image of the at least a portion of the object as a function of the received second signal.

16. The system of claim 15 further comprising:
a beam splitter positioned along the first path.

17. The system of claim 16 further comprising:
a quarter wave plate position along the first path between the beam splitter and the object.

18. The system of claim 15 wherein the light source is a diode laser.

19. The system of claim 15 wherein the first photo sensitive device is a position sensing detector.

20. The system of claim 15 wherein the second photo sensitive device is a photo diode array.

21. The system of claim 15 further comprising:

a third photo sensitive device at a third preselected position for detecting light reflected along a third path spaced from the first and second paths from the object and for generating a third signal representing information concerning the light detected along the third path; and

wherein the processing means is in communication with the third photo sensitive device and receives the third signal and generates a third image of the at least a portion of the object as a function of the third signal.

22. The system of claim 21 further comprising:

a fourth photo sensitive device at a fourth preselected position for detecting light transmitted from the light source along the first path and for generating a fourth signal representing information concerning the transmitted light; and

wherein the processing means is in communication with the fourth photo sensitive device and receives the fourth signal and processes the second signal as a function of the fourth signal.

23. An optical measurement system comprising:

a light source positioned to transmit light along a first path for illuminating at least a portion of the object;

a first photo sensitive device at a first preselected position for detecting light reflected along a second path spaced from the first path from the object and for generating a first signal representing

information concerning the light detected along the second path;

a second photo sensitive device at a second preselected position for detecting light retro-reflected along the first path from the illuminated portion of the object and for generating a second signal representing information concerning the light detected along the first path; and

processing means, in communication with the first and second photo sensitive devices, for receiving the first signal and for generating a first image of the at least a portion of the object as a function of the received first signal, and for receiving the second signal and for generating a second image of the at least a portion of the object as a function of the received second signal, the processing further for determining at least one dimension of the object based on the first image and at least one second dimension of the object based on the second image.

24. An optical measurement system comprising:

a light source positioned to transmit light along a first path;

a deflector for deflecting the light transmitted along the first path to a second path spaced from the first path for illuminating at least a portion of the object;

a first photo sensitive device at a first preselected position for detecting light reflected along a third path spaced from the first and second paths from the object and for generating a first signal representing information concerning the light detected along the third path;

a second photo sensitive device at a second preselected position for detecting light retro-reflected along the second path from the illuminated portion of the object and for generating a second signal representing

information concerning the light detected along the first path;

processing means, in communication with the first and second photo sensitive devices, for receiving the first signal and for generating a first image of the at least a portion of the object as a function of the received first signal, and for receiving the second signal and for generating a second image of the at least a portion of the object as a function of the received second signal, the processing further for determining at least one dimension of the object based on the first image and at least one second dimension of the object based on the second image.

25. The system of claim 24 wherein the deflector includes an acousto-optic deflector.

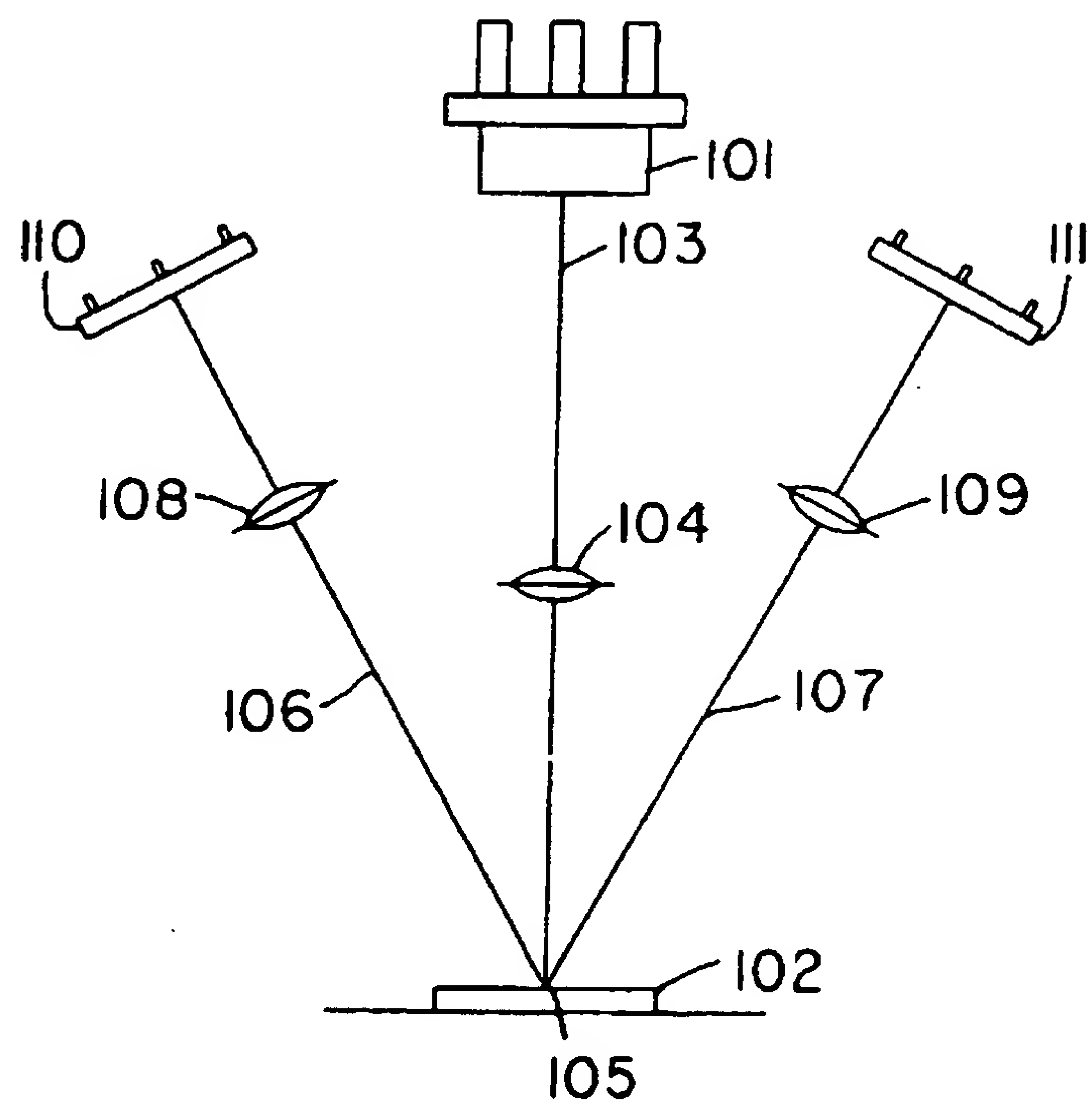


FIG. 1
PRIOR ART

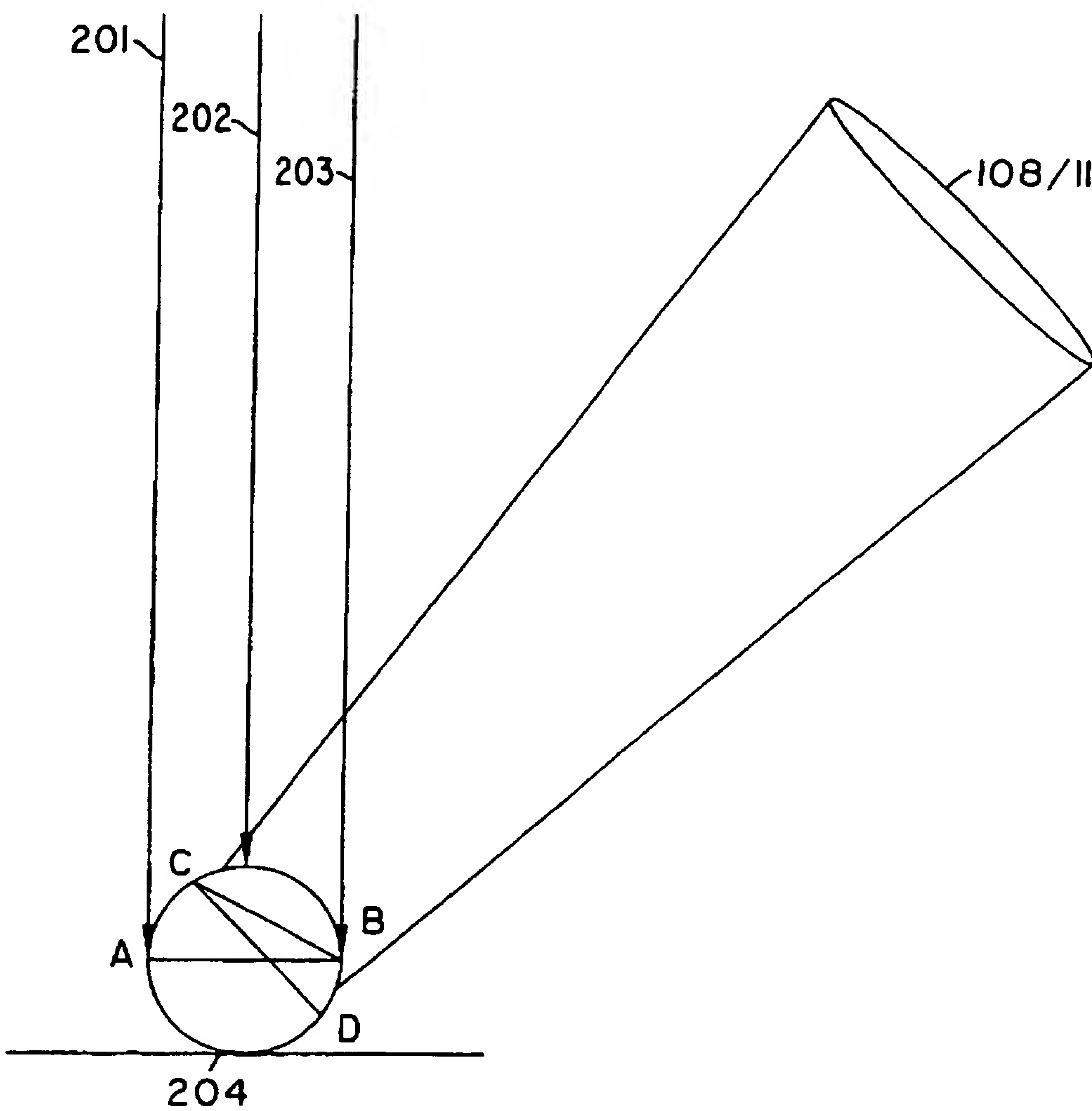


FIG. 2

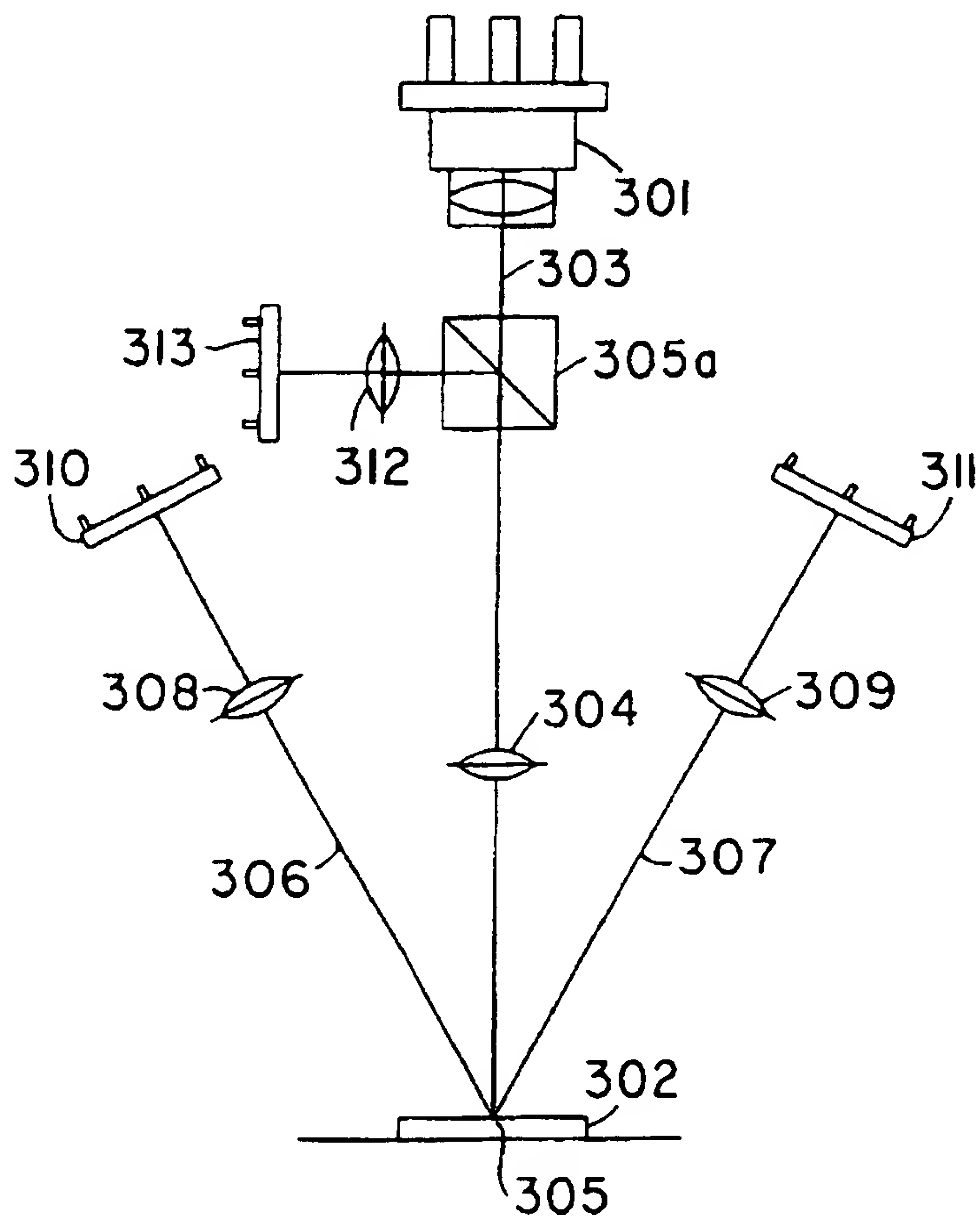


FIG. 3

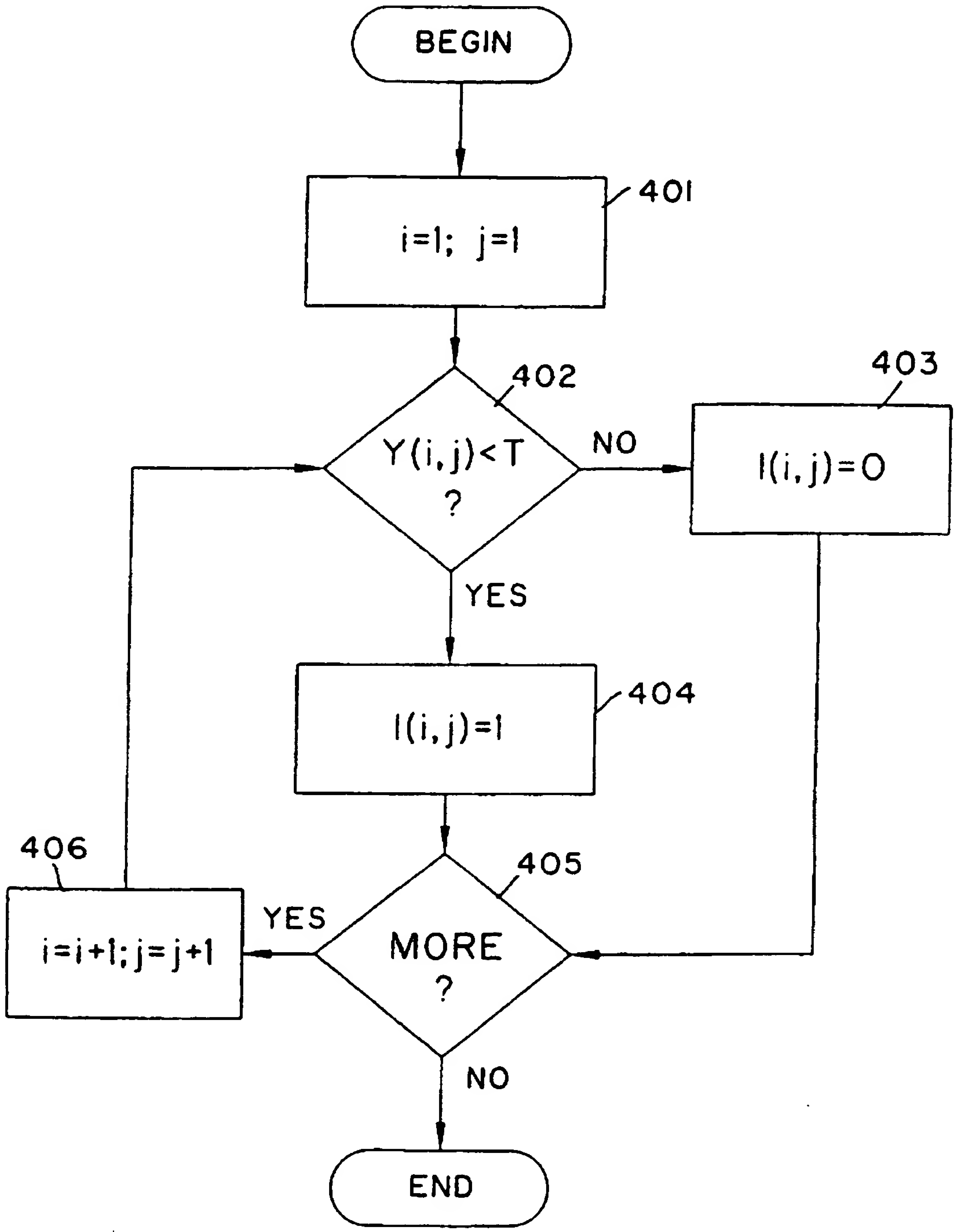

BEGIN
i=1; j=1
401
402
Y(i,j)<T
?
NO
403
I(i,j)=0
YES
404
I(i,j)=1
405
MORE
?
YES
406
i=i+1; j=j+1
NO
END

FIG. 4

Y

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

$I(i,j)$ X

FIG. 5

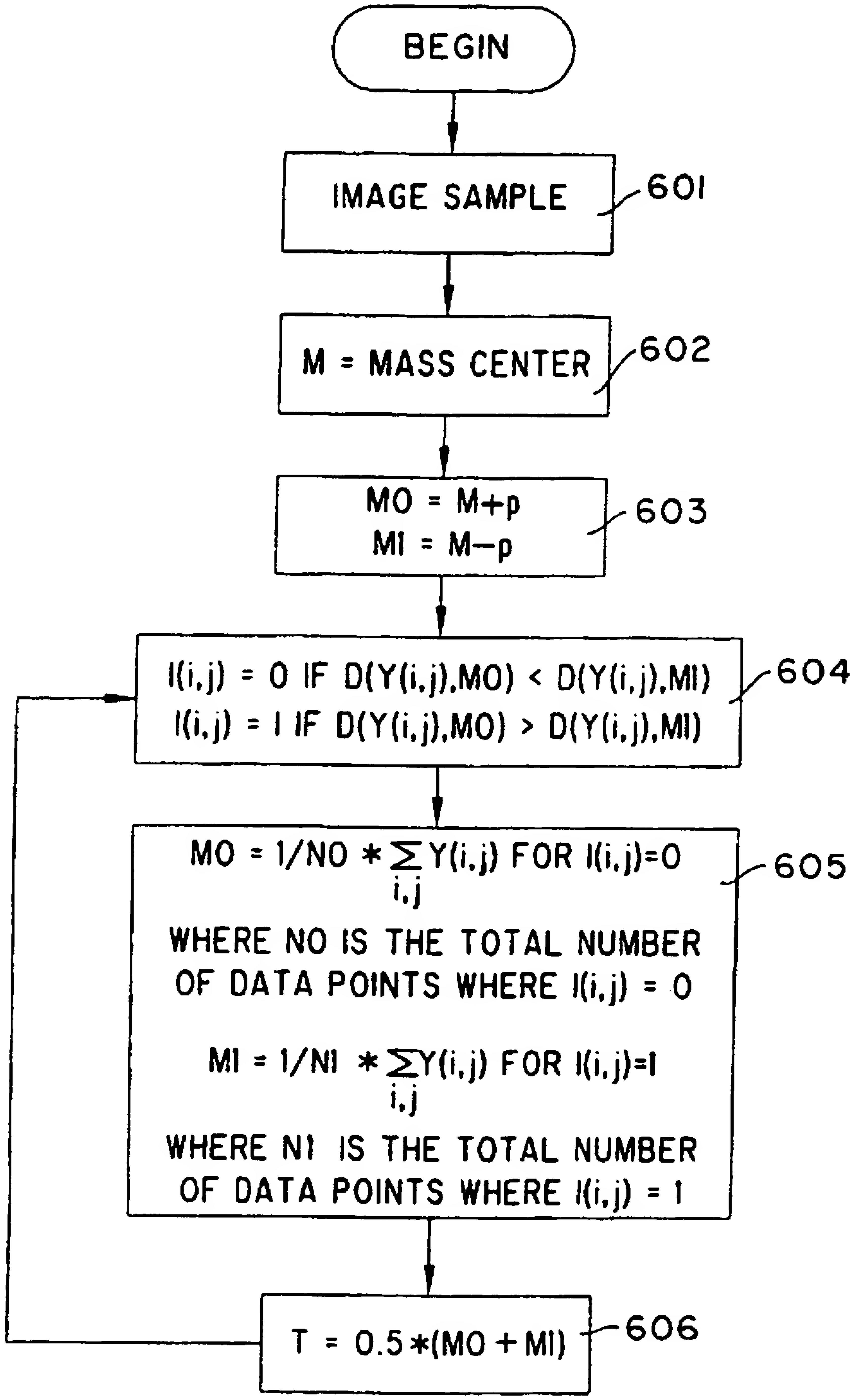

BEGIN
IMAGE SAMPLE
601
M = MASS CENTER
602
MO = M+p
MI = M−p
603
I(i,j) = 0 IF D(Y(i,j),MO) < D(Y(i,j),MI)
I(i,j) = I IF D(Y(i,j),MO) > D(Y(i,j),MI)
604
MO = 1/NO * Σ_{i,j} Y(i,j) FOR I(i,j)=0
WHERE NO IS THE TOTAL NUMBER OF DATA POINTS WHERE I(i,j) = 0
MI = 1/NI * Σ_{i,j} Y(i,j) FOR I(i,j)=1
WHERE N1 IS THE TOTAL NUMBER OF DATA POINTS WHERE I(i,j) = 1
605
T = 0.5*(MO + MI)
606

FIG. 6

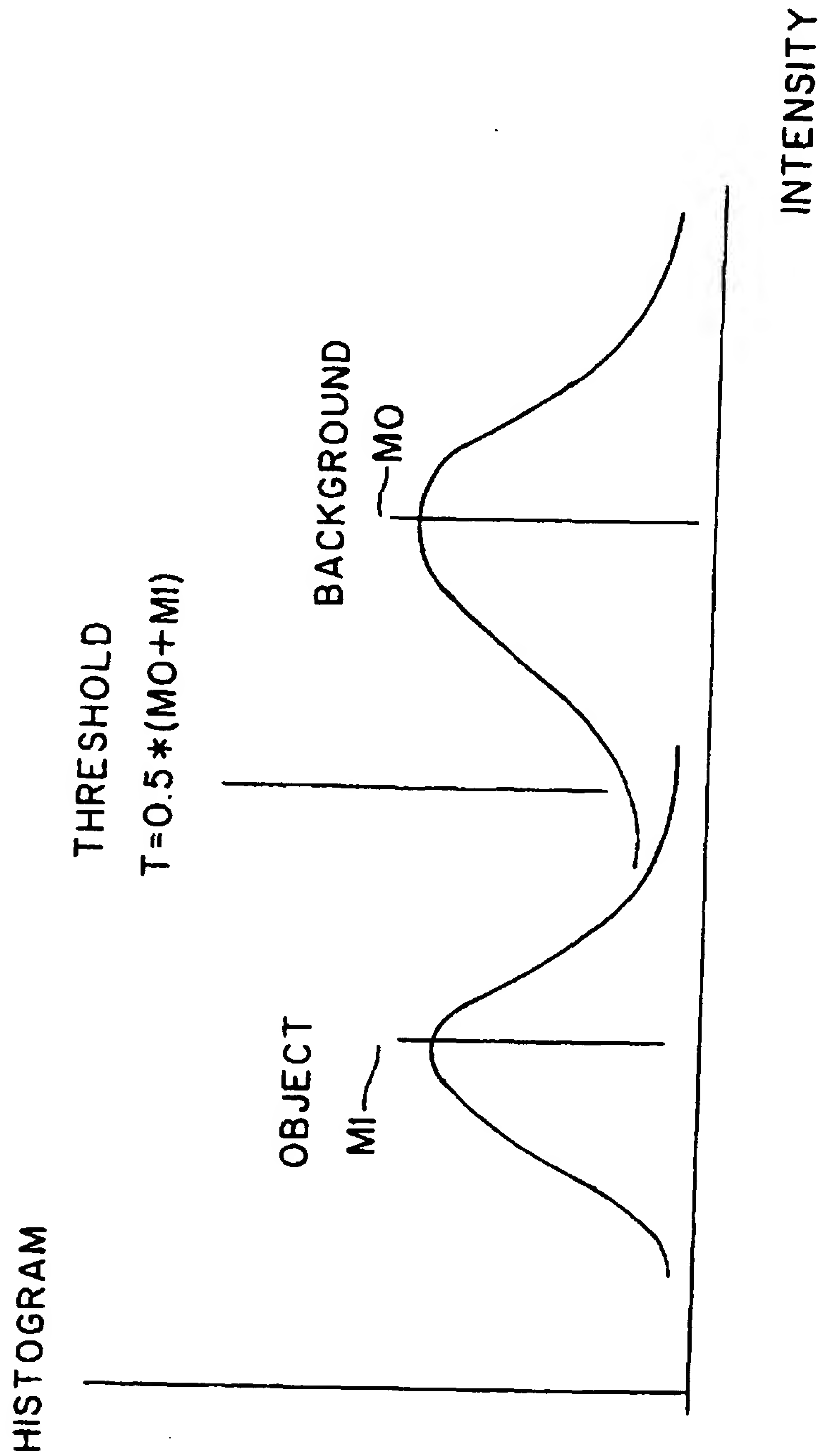

HISTOGRAM
OBJECT
MI
THRESHOLD
T=0.5*(MO+MI)
BACKGROUND
MO
INTENSITY

FIG. 7

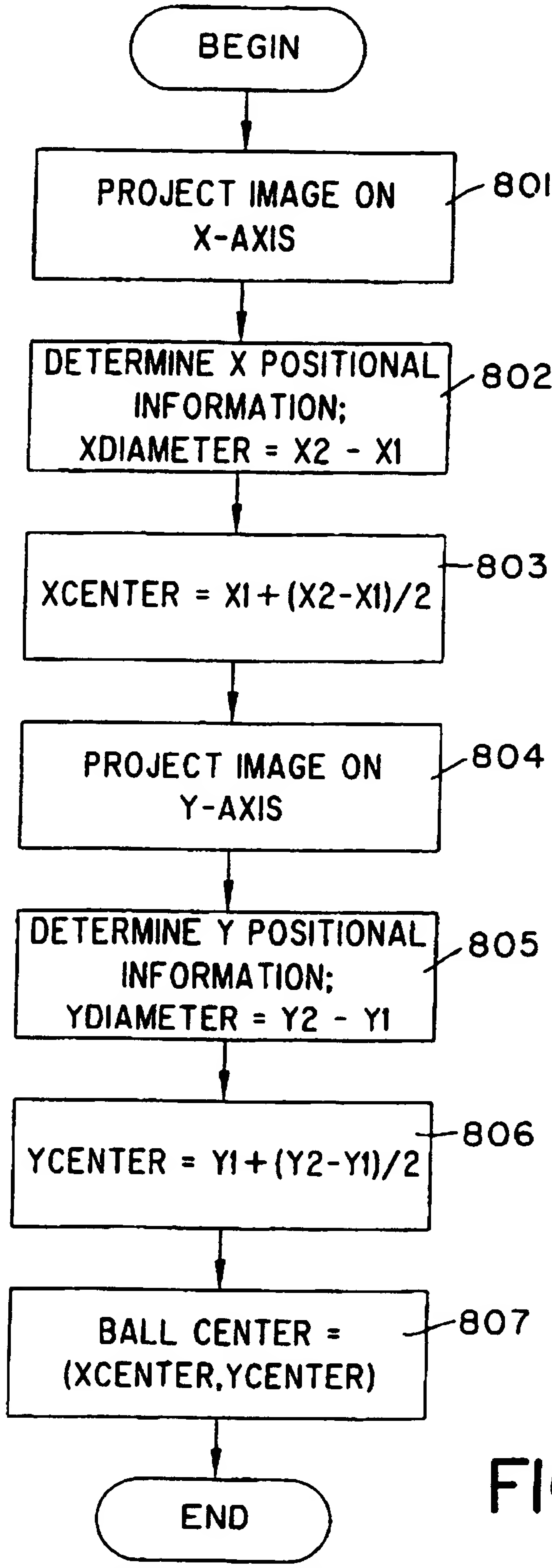

BEGIN
PROJECT IMAGE ON X-AXIS
801
DETERMINE X POSITIONAL INFORMATION; XDIAMETER = X2 - X1
802
XCENTER = X1 + (X2-X1)/2
803
PROJECT IMAGE ON Y-AXIS
804
DETERMINE Y POSITIONAL INFORMATION; YDIAMETER = Y2 - Y1
805
YCENTER = Y1 + (Y2-Y1)/2
806
BALL CENTER = (XCENTER,YCENTER)
807
END

FIG. 8

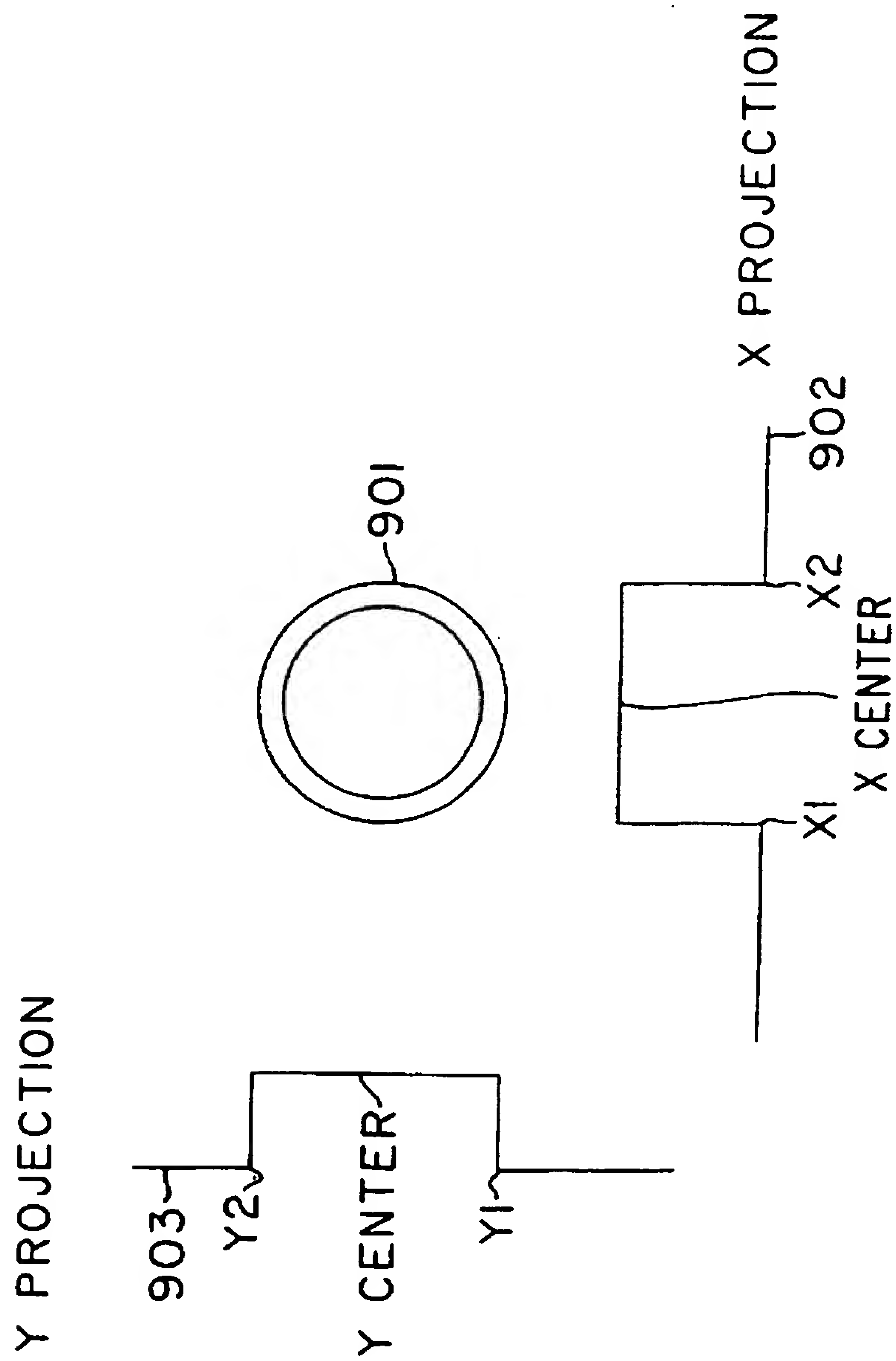

X PROJECTION
902
901
X2
X CENTER
X1
Y PROJECTION
903
Y2
Y CENTER
Y1

FIG. 9

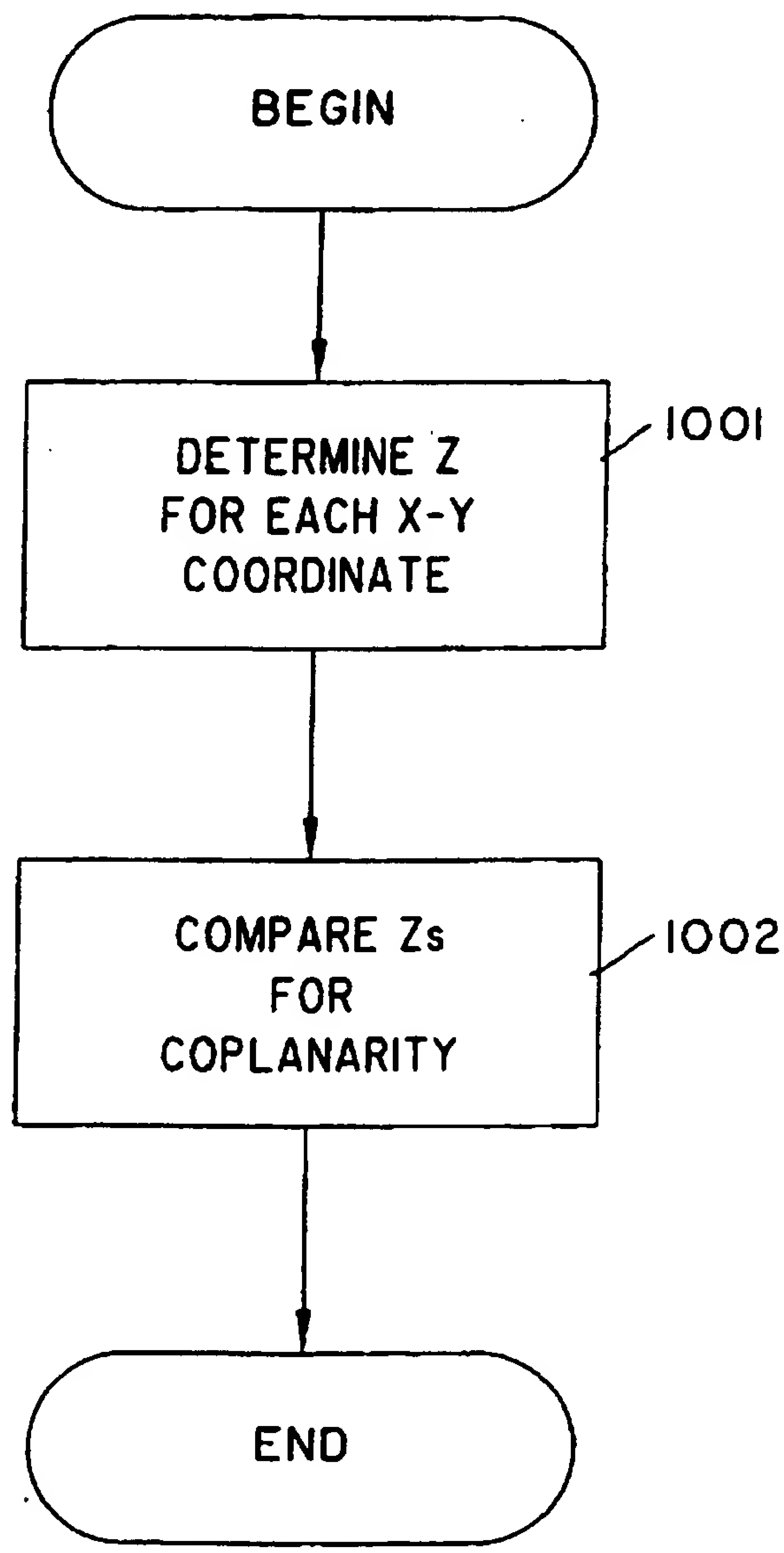

BEGIN
DETERMINE Z FOR EACH X-Y COORDINATE
1001
COMPARE Zs FOR COPLANARITY
1002
END

FIG. 10

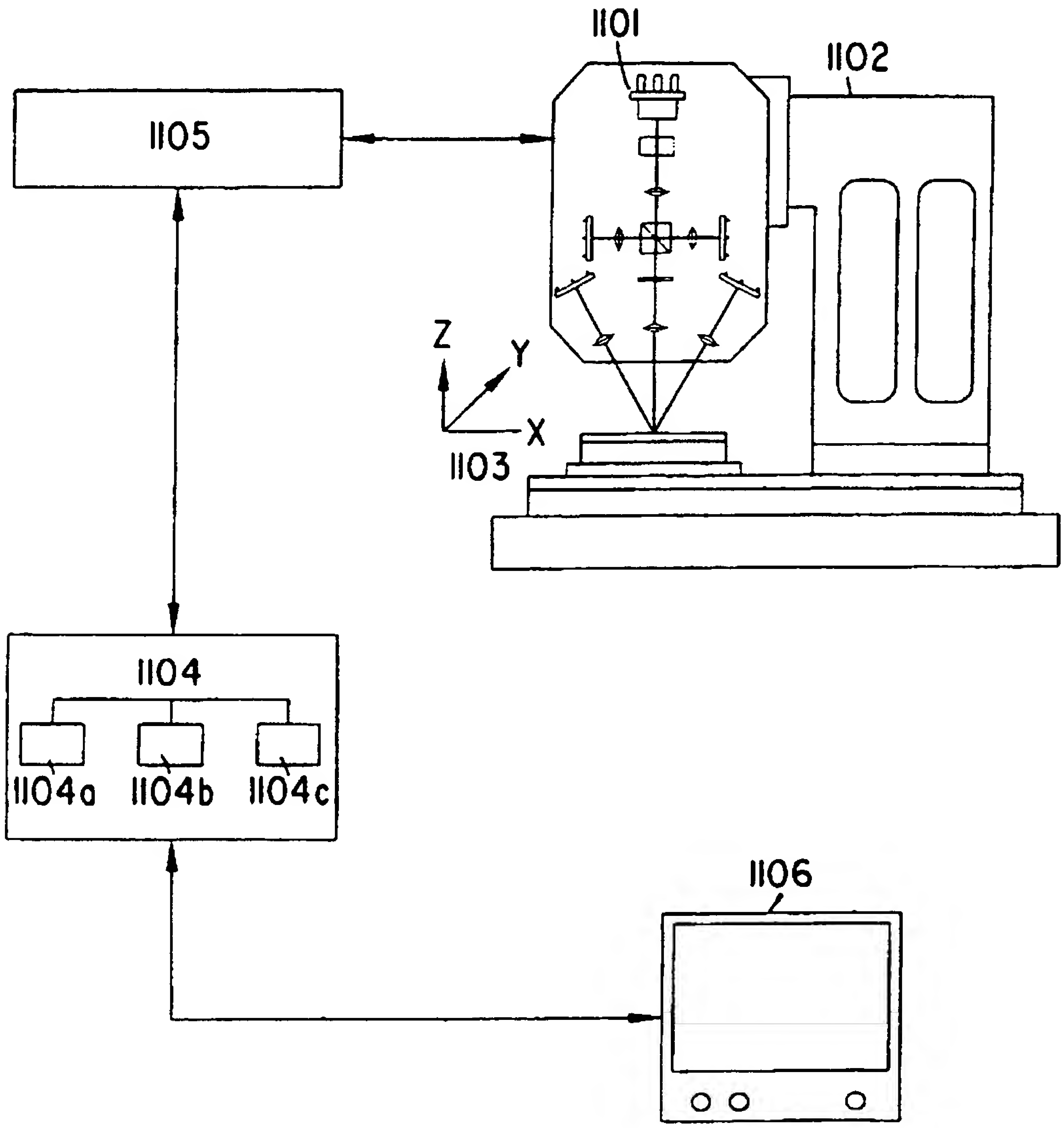
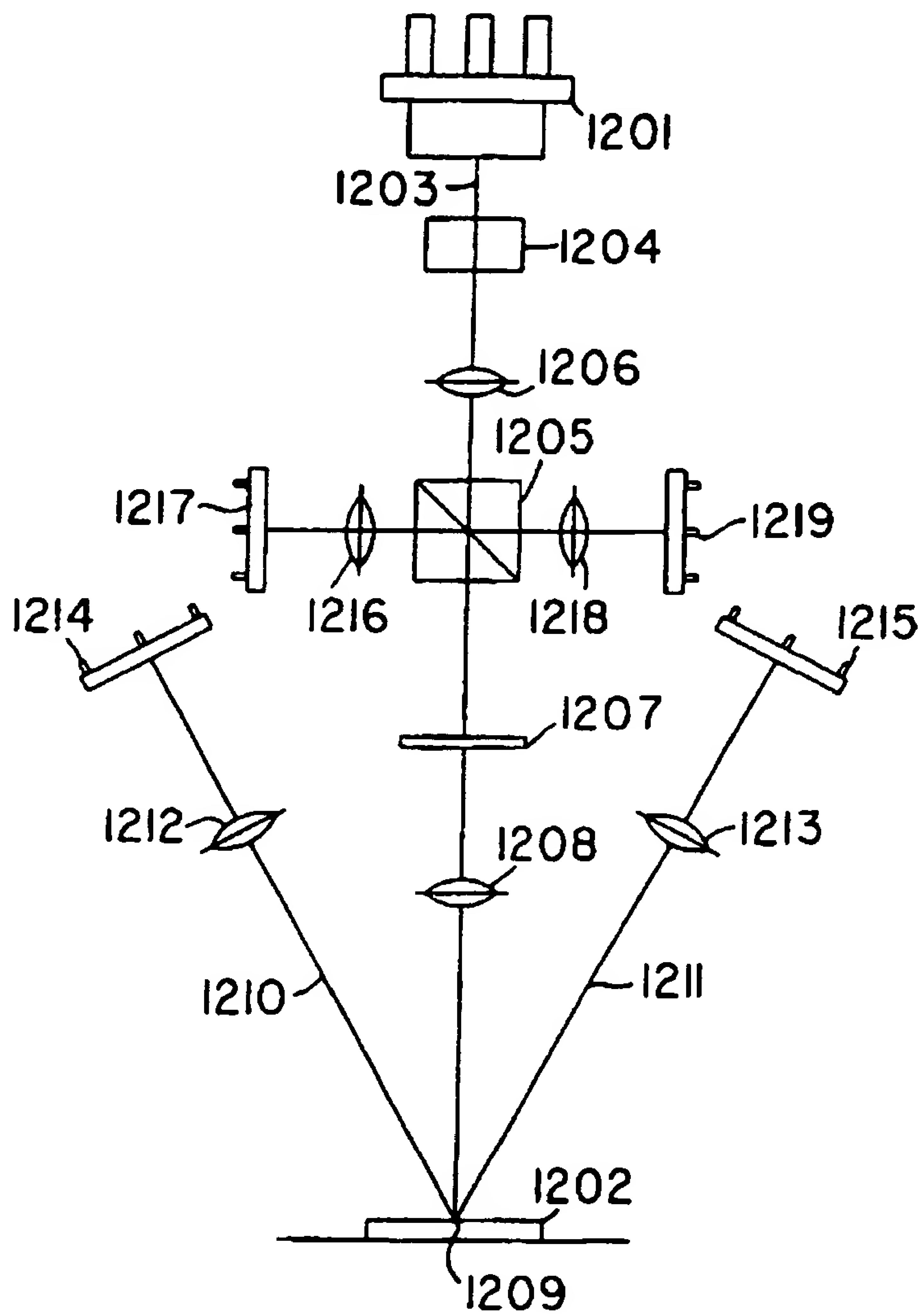


FIG. 11


1201
1203
1204
1206
1205
1217
1219
1214
1216
1218
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1207
1212
1208
1213
1210
1211
1202
1209

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/10833

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G01B 11/03, 11/08; G06T 5/40
US CL :382/145, 154, 172; 356/376
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 5,347,363 A (YAMANAKA) 13 September 1994, col. 15, line 16 - col. 17, line 6.	1-4, 8, 9, 10, 12, 13, 15, 19, 21, 23 -------- 5-7, 11, 14
X -- Y	US 4,441,124 A (HEEBNER ET AL.) 03 April 1984, col. 2, line 46 - col. 3, line 68.	1, 10, 13, 15, 16, 18, 20-25 -------- 17
Y	US 5,311,598 A (BOSE ET AL.) 10 May 1994, col. 2, lines 10-21.	5, 11

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 AUGUST 1997	30 OCT 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	BRIAN P. WERNER Telephone No. (703) 306-3037

Form PCT/ISA/210 (second sheet)(July 1992)*

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,075,872 A (KUMAGAI) 24 December 1991, col. 2, line 14 - col. 3, line 63.	6, 7, 14
Y	US 4,824,251 A (SLOTWINSKI ET AL.) 25 April 1989, col. 4, lines 29 - 34.	17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/10833

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

348/87, 92, 94, 126, 131, 139; 382/106, 141, 143, 145, 146, 147, 148, 149, 150, 151, 152, 154, 172; 356/3.01, 3.03, 3.06, 3.08, 4.03, 237, 359, 375, 376, 384, 394; 364/560, 562, 563; 250/559.23, 559.24, 559.31, 559.34, 559.38; 355/52, 53; 437/8

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

COMPENDEX, IEEE

search terms: retro reflect?, three dimension?, z height, ball grid array, pin grid array